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I. INTRODUCTION.

This Paper is an account of the results of investigations upon Silver-leaf disease since 1919, when the third instalment was published. These researches have been assisted financially by the Ministry of Agriculture and Fisheries, and have been carried out chiefly at Cambridge and at the John Innes Horticultural Institution, Merton. During the last two or three years some of the experimental work has been done at the East Malling Fruit Research Station, by the courtesy of Mr. R. G. Hatton, and at Heston, Middlesex, where Mr. W. J. Lobjoit kindly placed a considerable number of Victoria Plums at our disposal for experimental purposes.*

Since Brooks and Bailey wrote the paper "Silver-leaf Disease, III.," few papers on this malady have appeared, the most notable being those by Bintner (1) and Cunningham (9). Both of these papers are essentially confirmatory of the results published in the earlier reports of the present investigation, Cunningham's account dealing with the disease as it occurs in New Zealand. Bintner (1) attempts to draw a distinction between "true" Silver-leaf disease caused by *Stereum purpureum* and "false" Silver-leaf disease, due to physiological causes, but there are serious difficulties in this classification, as will be mentioned later.

Silver-leaf disease probably occurs to some extent wherever plums and apples are grown on a large scale. It is common in Holland and by no means rare in Denmark and other European countries. It is widespread in New Zealand (9), and is of frequent occurrence in South Africa, whence a culture of a fungus isolated from a silvered fruit tree upon being sent to us was identified as *Stereum purpureum*. Güssow (11) recorded the existence of this disease in Canada in 1912, and recently one of us has been informed that it commonly occurs in the Oregon apple-growing district. The difference in intensity of the disease in various parts of the world is partly due to varietal differences in the kinds of apples and plums grown, and also partly to climatic differences, the disease being at its worst in countries where the summers are relatively wet and the winters comparatively mild.

* For a short period Mr. W. Buddin (now of University College, Reading) assisted one of us in these investigations. His help is gratefully acknowledged.

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II. FIELD OBSERVATIONS.

(1) *Hosts affected by silver-leaf disease.*

It is not proposed to give a complete list of new host plants seen to be affected since 1919 ; only those of special interest will be mentioned.

Silvered sucker shoots of elm connected with old stumps have been twice seen, also silvered hawthorn shoots. A Plant of *Rosa sericea*, var. *Pterocantha*, was killed by *Stereum purpureum* in the Cambridge Botanic Gardens in 1920, but it is not known whether the foliage was silvered before death. Mr. R. G. Hatton informs us that a plant of *Rosa rugosa* which appeared sickly during the summer of 1922 and was perhaps silvered, died at the end of the year and produced abundant fruit-bodies of *Stereum purpureum*, by which doubtless it had been killed. It is regrettable to have to announce this attack on roses, but with so many plants in the same family liable to succumb to the fungus, it does not seem surprising that roses also should occasionally fall a prey to it. As reported in an earlier paper (2) we have again seen examples of beech and birch trees killed by *Stereum purpureum* without the symptoms of silvering being manifest.

Since paper III. of this series appeared, two silvered pear trees have been seen. One was a Beurre Hardy pear, which had been unsuccessfully regrafted, the other was one of the Conference variety. A silvered stool bed of Portugal quince has also been seen. It seems unlikely that pear trees will become at all susceptible to silver-leaf disease for innumerable inoculations of different varieties have been performed, all of which have been unsuccessful. In these experiments the fungus spread only to a limited extent in the tissues and then quickly perished.

Serious cases of infestation of sweet cherries have not been encountered, but silver-leaf disease is often important in Morello cherries, where the symptoms and course of the malady are the same as in Victoria plums.

Peach trees are often liable to serious attack, and in the Worthing district where peaches are grown on a large scale under glass, this is perhaps the most serious trouble the grower has to contend with. The physical conditions of a peach-house are ideal for the development of silver-leaf disease if precautions are not taken to prevent infection by *Stereum purpureum*. Until recently no such precautions were taken, and several growers appeared to be unaware of the nature of the disease, one even allowing a dead plum tree covered with the fungus to remain just outside the door of one of the glass-houses. Here also the course of the disease is essentially the same as in plums, the wounds made in pruning the trees affording means of entry for the fungus.

In recent years two varieties of apples have shown special susceptibility to silver-leaf disease, and under certain conditions appear as liable to attack as is the Victoria plum. These are Newton Wonder and Early Victoria (often called Emneth Early in the Wisbech district). In these varieties the disease is often rapidly fatal. The varieties Lord Grosvenor, Grenadier, Lord Suffield, Blenheim Orange and Bramley's Seedling are moderately susceptible, but there is usually a prolonged struggle between host and parasite, and with Bramley's Seedling complete recovery is likely. Apples such as Lane's Prince Albert, Worcester Pearmain and Cox's Orange Pippin are only occasionally affected.

Earlier papers have discussed the susceptibility of different varieties of plums, the most resistant being Pershore, Early Rivers, and Greengage, although even these are occasionally attacked. In 1919 (3) it was reported that it was easy to induce silvering in Pershore plums by inoculation with *Stereum purpureum*, but such trees almost invariably recover, the reasons for which will be discussed later. One or two severe attacks of Monarch plums have been noticed where the trees had been somewhat drastically cut, but this variety, together with Pond's Seedling, Belle de Louvain, Transparent Gage, etc., is tolerably resistant.

(2) *Relation of previous treatment to severe outbreaks of silver-leaf disease.*

Neglect of silver-leaf disease is now comparatively rare in the fruit-growing districts of this country and consequently widespread attacks are less frequently seen than hitherto. In recent years epidemic occurrences of the disease have been usually associated with some previous inadvertent error in the treatment of the trees, which has resulted in innumerable exposures liable to invasion by *Stereum purpureum*. A few such examples will be described. After the war, tractors were introduced into many fruit plantations, and in apple orchards the lower branches of the trees were frequently cut away to facilitate cultivation. In the course of a year or two, several plantations of susceptible varieties such as Early Victoria and Newton Wonder became almost universally affected by the disease, it being clear that the fungus had entered through the exposures left unprotected after removal of the lower branches. In one plantation more than 1,000 Early Victoria trees became silvered after such treatment, many of which were killed outright. In another area, old Bramley's Seedling trees had been similarly treated, with the result that many became silvered although the disease did not make such rapid progress as with the other varieties mentioned.

Another operation which not infrequently results in silver-leaf disease is the re-grafting of apple trees, and several examples of veritable epidemics caused thereby have been seen. With susceptible varieties such as Newton Wonder, the risk of infection in re-grafting is very great as the following example shows. In November, 1920, 150 Newton Wonder trees, nine to ten years old, were cut

back and were re-grafted with Bramley Seedling scions in March, 1921. In the following August silvering began to appear and the disease spread so rapidly and universally that practically every tree was killed during the next winter. In this case Stockholm tar was applied to the cut extremities, but, as will be seen later, this substance is a very imperfect protection. Where "pug"—a mixture of clay and cow dung, has been used in re-grafting, the losses have been far less severe.

If susceptible varieties of plums are drastically pruned or thinned there is similar danger of infection. For instance, Czar plum trees badly affected by *Monilia cinerea* (brown rot) in 1920 were drastically cut during the winter of 1920-21 to remove diseased branches, with the result that the following summer most of the trees were severely attacked by silver-leaf disease. Other Czar trees from which the branches killed by *Monilia cinerea* had not been removed, remained free from silver-leaf disease.

In nurseries also there is sometimes a considerable incidence of this disease, particularly in plums, which is associated with certain operations carried out in the routine of propagation. Plums are usually budded on to a stock and when the bud proliferates in the spring, the stock is cut back to form a stub two or three inches long to which the developing shoot is tied, thus obviating the necessity of staking. The stub is finally cut away during the autumn or winter. In this practice two opportunities are afforded for the entry of *Stereum purpureum*, one at the time when the stock is cut back, and another when the stub is removed. During the last three years numerous instances of infection where one or other of these exposed surfaces has not been protected have come to our notice. From the periods at which cutting of this kind is done, infection will often not result in silvering until the second year's growth of the bud.

(3) *Stock influence.*

It was pointed out in 1919 (3) that young Victoria plum trees worked on Pershore stocks were as readily infected artificially with *Stereum purpureum* as those worked upon other stocks which are commonly used. As will be shown later, the chief varieties of plum stocks are susceptible to silver-leaf disease when deliberately inoculated, but notwithstanding this, observation in the field indicates that the nature of the stock may indirectly influence the relative susceptibility of such a variety as Victoria. For example, in an East Anglian fruit plantation Victoria plums about twenty-two years old showed a striking difference in susceptibility according as to whether the tree was worked on the Myrobolan or the Common Plum stock. Where the latter had been used, the habit of the trees was more open, with shorter lateral growth and apparently harder wood than usual in this variety; correlated with these changes there was a marked reduction in the disease. An additional factor must, however,

be taken into consideration here as the Common Plum stock had been worked at the height of two or three feet, so that a considerable portion of the trunk of the tree belonged to the stock, whereas with the Myrobolan stock the trees had been worked in the usual way. Whatever be the explanation, there is no doubt about the profound change in habit which the Common Plum stock had induced in this plantation, and the observation gives rise to the hope that means may be found to check somewhat the exuberant growth of the variety Victoria and thereby render it less liable to the broken limbs which are one of the commonest sources of infection. With the assistance of Mr. R. G. Hatton, of the East Malling Research Station, the possibilities of improvement in this direction are being explored, but from the nature of the work, it will be a long time before it can be ascertained whether success is likely to be achieved.

III. THE SUSCEPTIBILITY OF PLUM STOCKS TO SILVER-LEAF DISEASE.

As a preliminary to other enquiries it was thought desirable to test the susceptibility of different kinds of plum stocks by artificially inoculating them with *Stereum purpureum*. The stocks used for this purpose were two to three years old and the test was applied in the following ways :—

(*a*) The main stem was inoculated with a small portion of a sporophore of *Stereum purpureum*.

(*b*) The stock was grafted with a scion of a Victoria plum which had been deliberately infected some time previously with *Stereum purpureum*, with a view to ascertaining whether the fungus would readily pass from the scion into the stock.

The following stocks were experimented with in this fashion : Black Damask D, St. Julien D, Myrobolan B, Common Plum, Common Mussel, Broad Leaved Shiny Mussel, Brompton, Pershore and Brussels.

Not a single one of these stocks proved immune to invasion by *Stereum purpureum* in both these ways. Where the inoculation was carried out by inserting the fungus in the main stem of the stock, the number of successes was always lower than when such varieties as Victoria or Czar were inoculated in the same manner, but about fifty per cent. of the inoculations on the following stocks resulted in silver-leaf : Black Damask D, St. Julien D, Common Plum, Broad Leaved Shiny Mussel, Brompton, Pershore and Brussels. In Myrobolan B, however, of eight inoculations of this kind none were successful, and in Common Mussel only one of eight inoculations caused silvering. Where infected Victoria scions were worked on these stocks invasion was much more certain, and, with one exception, of four of each of these worked stocks, all became

invaded by the fungus, many being killed outright by it with fructifications of *Stereum purpureum* appearing at soil level. It is clear that if sufficient opportunity be afforded, all the above stocks can be invaded by this fungus. This is not surprising when it is borne in mind what very diverse kinds of plants can be killed by *Stereum purpureum* if it reaches the internal tissues. It may be urged with some reason that susceptibility to artificial inoculation may be no criterion of natural suceptibility, but experience has shown that there is usually a correlation between the two. After the critical nursery phase there is little opportunity for the stock to be infected except through the variety which has been worked upon it. In spite of the above results, we are of the opinion that by careful attention to the stock and the manner of working it, a harder type of growth, less susceptible to silver-leaf disease, in some of the chief commercial varieties of plums, may perhaps be induced.

IV. PATHOGENICITY OF DIFFERENT STRAINS OF *STEREUM PURPUREUM*.

In 1913 (2) and again in 1919 (3) it was pointed out that *Stereum purpureum* obtained from a saprophytic source was just as capable of causing silver-leaf disease as the fungus obtained from an affected plum tree. Additional experiments have confirmed the truth of this statement. For instance, the fungus taken from dead poplar stumps both in Kent and in Denmark have readily induced silver-leaf disease in plums. Hence from the pathogenic standpoint, *Stereum purpureum*, on whatever substratum it may be found, must be looked upon as a facultative parasite.

As is well known, the fructifications of this fungus are exceedingly variable in form and to some extent in colour. Minute microscopic differences also are to be found in various collections of the fungus, but from the pathogenic standpoint these structural differences are immaterial. Mr. E. S. Salmon sent us material of *Stereum purpureum*, variety *atromarginata*, some time ago and this was found to be readily capable of inducing silver-leaf disease. Recently Burt (7) in America has distinguished under the name *Stereum rugosiusculum* Berk. and Curt, the forms bearing hymenial cystidia from *Stereum purpureum* (Pers.), Fr., but in our experience this separation appears doubtfully valid. Numerous collections of the fungus from different substrata have been examined, and, as pointed out by one of us elsewhere (6), there seems to be every possible intergrade between forms possessing many hymenial cystidia and forms devoid of them. Forms which would be included under the name *Stereum rugosiusculum* by Burt have as readily induced silver-leaf disease as *S. purpureum* in the narrow sense. We consider that there is no real distinction between these forms and that it is best to use only the species name, *purpureum*.

This fungus will grow saprophytically or semi-parasitically upon almost any kind of dicotyledonous woody material in temperate regions, as long as the tissues are moribund or have only recently died. In nature it does not often occur upon tree stumps and logs after invasion by other fungi. Upon such material it is either the first micro-organism to develop, or it is not likely to occur thereon at all. This mode of life is intimately associated with its pathogenic proclivities. This species is of common occurrence upon stumps of all kinds of broad-leaved trees, except oak, upon which it scarcely ever occurs, perhaps because *Stereum hirsutum* almost invariably begins to develop upon this at an early stage. Until recently it was thought not to occur upon coniferous wood, but Mr. Oldham, of the Ministry of Agriculture, has reported it on larch stumps and one of the writers has seen it growing profusely upon pine logs.

V. THE EFFECT OF *STEREUM PURPUREUM* UPON INVADED TISSUES.

The presence of *Stereum purpureum* in the woody parts of such hosts as plum and apple causes a well-marked browning of the tissues, owing to the accumulation therein of gummy substances produced indirectly by the action of the fungus. It has already been pointed out (2) that a branch in the early stage of attack has only a sector of the wood invaded, but ultimately the whole of the tissues become permeated by the fungus, when the branch dies and the parasite produces its fructifications during wet weather. It is characteristic of this disease for the leaves of such a branch in lateral proximity to the discoloured wood or above it to assume a silvery appearance owing to the excretion by the fungus into the transpiration current of some substance which indirectly brings about this change in the foliage. From inoculations of straight branches of plum trees in the dormant season it seems clear that the wood discoloured by the fungus is no longer functional in carrying the water stream, for buds actually on the line of advance of the fungus fail to open and rapidly collapse owing to the cutting off of the water supply. Buds laterally just outside the invaded tissues expand and usually give rise to silvered foliage, as do those some distance above the discoloured wood, even though in the same vertical plane, owing to lateral diffusion from the uninvaded tissues. Buds which are remote from the discoloured wood give rise to healthy foliage. In some recent inoculation experiments it has become apparent that the influence of the substance secreted by the fungus is felt sometimes *below* the discoloured wood as well as above it. In one tree silvered foliage appeared nine inches below the lowest tissues actually invaded by the fungus. The substances secreted by the fungus therefore pass to a limited extent downwards as well as upwards. This is due either to static diffusion or to a distinct downward flow in the vessels at certain times, as

suggested by Dixon (10). In this connection it may be pointed out that in some injection experiments with dyes, trees injected with eosin six inches above soil level in March were found permeated by the dye practically to the extremities of the roots when the tree was cut up in August. It is difficult to understand the conveyance of the dye to the ends of the roots solely by static diffusion but it is readily explicable on the assumption of a downward flow.

It has already been stated that the discolouration of plum and apple tissues invaded by the fungus is due to the accumulation of gum-like substances. Where a fungus invading woody tissues does not cause delignification, the occurrence of such gummy residues is one of the most wide-spread pathogenic phenomena. Different views have been expressed as to the origin of gum in the tissues of species of *Prunus*, which is sometimes a pathological phenomena not associated with parasitic invasion. Prillieux (13), Brooks and Bartlett (4) and others believe that starch or other living cell contents play an important part in gum formation, while Butler (8) holds that the gum is formed by hydrolysis of the walls of embryonic wood cells owing to abnormal excitation of the cambium. This divergence of opinion may partly be due to the fact that gum formation in the genus *Prunus* probably includes many processes which have not been separated clearly from one another. Gum formation in old woody tissues differs vastly from the degeneration of newly-formed wood cells into gum pockets as described by Butler (8). In fully-developed woody tissues discoloured by the action of *Stereum purpureum* gum is present both in the vessels and in the ray cells. In our opinion such gum is formed chiefly in the living cells, whence it passes into the vessels and is produced mainly from starch as a reaction to the presence of the fungus. In support of this statement it has been found that gum formation is most copious when the starch content of the wood is greatest ; for instance, the cut extremities of plum twigs kept in the laboratory produce large quantities of gum during the winter, but when the buds expand gum formation is much less. In these old tissues invaded by *Stereum purpureum* there is no indication of gum formation through the degeneration of the cell walls. As stated in the literature on the subject, gum formation frequently occurs in response to other kinds of injury besides parasitic invasion. In our work profuse gumming has occurred where plum trees have been injected with certain dyes such as gentian violet. Here gum formation was induced owing to the presence of minute quantities of a toxic substance, but where a more powerful poison was employed such as sodium arsenate, the tree was killed without gum being exuded.

There appear to be two kinds of gum formed in plum wood attacked by *Stereum purpureum*. One is a practically colourless substance except when seen in dense masses, which is soluble in warm water and readily stains with Delafield's hæmatoxylin ; this gum corresponds to that which often exudes from plum trees. The other type of gum found in invaded wood is yellow-brown,

insoluble in hot water, and does not stain with Delafield's hæmatoxylin. The first form is readily penetrated by the hyphæ and in fact can be used as a culture medium for the fungus, while the second type of gum is usually not penetrable by the fungus.

VI. NATURAL RECOVERY FROM SILVER-LEAF DISEASE.

The occasional recovery of silvered fruit trees without treatment is a well-known phenomenon, although it is frequently ignored by persons who claim to have discovered a cure after treating a few diseased trees. With a fungus inhabiting the woody parts of a tree it is clear that if its progress in those tissues be stayed, the symptoms of disease will disappear in time on account of the cessation of influence by the fungus and the formation of new healthy wood. Under these conditions the fungus is left isolated in the wood already discoloured, and it is only a question of time before it dies. As with other diseases of a parasitic nature, a continual struggle proceeds between host and parasite, and although in silver-leaf disease the fungus usually gains the victory over certain varieties of plums and apples, it by no means always achieves this. The struggle proceeding between host and parasite in woody tissues is probably of a different nature from that which takes place in a leaf attacked by a parasite ; for in plum wood most of the cells, e.g., the vessels and fibres, are dead and cannot react protoplasmically to the hyphæ. On the other hand, the medullary ray cells remain alive until the wood is several years old and can react forcibly to the parasite. The vessels are the chief elements of the wood invaded by *Stereum purpureum* and although dead they may exert a strong passive influence on the fungus according to their relative frequency, distribution and aeration.

On several occasions it has been noticed that natural recovery from the disease has been most pronounced after a hot, dry summer. For instance, after the drought of 1921 the recovery of Victoria and Czar plums was very pronounced and in our experimental area, where trees had become silvered through inoculation, fifteen to twenty per cent. of the trees of these varieties completely recovered. It is not yet known in what precise way weather conditions influence the rate of recovery.

Pershore plums, which readily develop silvery symptoms the first season after inoculation, almost invariably recover later. Upon examination, Pershore and Victoria trees which have recovered and pear trees which have been unsuccessfully inoculated, all show the same kind of reaction in the tissues. Where the fungus has spread appreciably in the wood there is the usual kind of discolouration due to the type of gum which is pale in colour and takes up Delafield's hæmatoxylin stain, but on the periphery is a narrow, much darker zone, containing gum of the other kind previously mentioned which does not

become stained with hæmatoxylin. Sections through the invaded tissues show hyphæ, apparently dead, in the lighter discoloured zone, but not in the darker, peripheral region which has apparently formed an impenetrable barrier to the fungus. All attempts to isolate and grow the fungus from the central region failed; doubtless the fungus was dead. It is not known how the darker gum in the outer zone is formed, although it is perhaps produced by a change in the other kind of gum, but it is undoubtedly a factor of great importance in checking the further development of the fungus and in bringing about recovery from the disease. With the formation of a barrier of this nature, the victory of the host is complete and the diseased tissues are isolated like an island. One of the differences between the Pershore and the Victoria varieties of plum lies in the more ready formation of this gum-barrier in the former, and with this is associated to a great extent the greater resistance of the Pershore variety to silver-leaf disease. In our inoculations of pear trees—and they have all hitherto been unsuccessful, the formation of the gum barrier has occurred almost immediately after inoculation, so that the fungus has spread very little in the tissues, thus explaining the almost complete immunity of this kind of fruit tree to silver-leaf disease.

VII. MODE OF NATURAL INFECTION BY *STEREUM PURPUREUM*.

Successful infection of plum trees in the field by spores of *Stereum purpureum*, resulting in silvered foliage, have previously been recorded (2, 3), but much more detailed information was required as to the way in which this fungus acts as a wound parasite. For instance, it was not known whether *S. purpureum* was more likely to invade freshly exposed tissues or woody parts that had been open to the weather and possibly already invaded by other micro-organisms; nor had it been ascertained whether the fungus could cause infection to an equal extent at all times of the year, or whether there was some special season of the year during which the fungus was most dangerous. Attention has recently been concentrated upon this part of the silver-leaf problem, for fuller knowledge of these aspects of the biology of *S. purpureum* is fundamental to any further elucidation of the disease.

It was decided therefore to carry out certain experiments on infection by *S. purpureum* under controlled laboratory conditions, to be followed as far as possible by comparable experiments in the field. For this purpose branches of Victoria or Czar plums, three to six years' old, were brought into the laboratory, placed in water, and their upper extremities—either freshly cut or after exposure to the atmosphere for some time, covered with a spore emulsion of *S. purpureum*, in order to ascertain whether infection could be brought about in this way. At first the extremities inoculated immediately after exposure were kept in a moist

atmosphere for several days by covering them with glass tubes containing moist cotton wool, but it was soon found that such protection did not materially affect the result. The first experiment of this kind was performed in February, 1922, and Victoria plum shoots eight inches long became completely permeated by the fungus in two months, whether the inoculated extremity had been kept in a humid atmosphere for many days or only for two days. Subsequent experiments showed that the provision of a saturated atmosphere even for a short period was unnecessary, and later experiments have been performed by leaving the inoculated extremities exposed to the atmosphere. In these earlier experiments several shoots which had been completely invaded by the mycelium—as shown by sections, developed fructifications of *S. purpureum* at the level of the water. Two conclusions were to be drawn from these experiments :

(1) That under laboratory conditions spores of *Stereum purpureum* could infect living plum wood and that the mycelium arising therefrom rapidly permeated the wood.

(2) That a very humid atmosphere was unnecessary for infection.

It may be added that control experiments sometimes became contaminated by moulds, especially where the twigs were covered by glass tubes for many days, but the amount of discolouration below the exposed surface was infinitesimal in comparison with twigs invaded by *S. purpureum.*

The next experiment was to compare the rate of invasion of living and dead (autoclaved) plum twigs. Here the autoclaved shoots showed little penetration by *S. purpureum* and were often badly contaminated with moulds, whereas the living twigs became rapidly permeated as before. This result suggested that *S. purpureum* may more readily invade healthy wood than tissues which have been already killed by some other means.

Another experiment of a similar kind carried out in May, 1922 was framed to test the influence of the age of the wood upon liability to infection by *S. purpureum.* For this purpose Victoria twigs, one year old, two years old, and three years old, were simultaneously inoculated with a spore emulsion. After an interval they were all found to be similarly invaded. The possibility of the third year wood being invaded from infected first year wood can be excluded, because the discolouration in the oldest wood was as extensive as that in the youngest wood and also because the lateral spread of the mycelium in such tissues is only slight. Plum wood retains its medullary ray cells in a living condition for a number of years, and it is probably that all such wood containing living cells is liable to invasion by this fungus. These results agree with certain field observations in which silver-leaf disease has appeared in connection with pruning one year old shoots as well as after cutting back older twigs. On the other hand wood quite recently formed from the cambium does appear to

resist invasion by the fungus from older wood, as has been pointed out in an earlier paper (2).

In the next experiment, carried out in June, 1922, the twigs inoculated as before were exposed to outdoor conditions : (*a*) in intense insolation, (*b*) in shade, inoculated controls being kept at the same time in the laboratory, and uninoculated controls in all three places. Within three weeks all the inoculated shoots, whether kept in the sun, shade or in the laboratory, were infected to the extent of several inches, while only one of the uninoculated controls showed discolouration of more than a millimetre below the exposed surface, this exceptional twig having been casually invaded by some unknown fungus. Hence infection of such shoots by *Stereum purpureum* can proceed even where the tissues are exposed to direct insolation.

Having elaborated a technique for the study of invasion by *Stereum purpureum*, the experiments are being continued month by month to ascertain whether the condition of the wood is a factor of importance, and to determine whether infection of exposed surfaces on trees *in situ*, takes place in the same way as in cut shoots. As far as these experiments have proceeded, infection appears to take place on the trees as in the experiments described above. It is safe to conclude that *Stereum purpureum* is able to infect freshly exposed plum wood, including wood only one year old, and that under suitable conditions invasion is very rapid. It is also probably true that this fungus infects fresh wood more readily than wood which has already been killed, e.g., by the action of other micro-organisms.

While the above experiments were being carried out, other experiments, of a less carefully controlled nature, were also being performed in the field, partly with the view to ascertaining whether any particular type of wound was specially liable to invasion and partly again to determine the relationship of length of exposure of the wound to risk of infection. In the experiment on the determination of the optimum period of exposure of a wound for infection, branches were sawn off Victoria and Czar plum trees close to a side branch and an emulsion of spores was applied either directly or at certain intervals up to eight months after the wound had been made. Of a large number of inoculations (usually about seventeen for each interval) none resulted in silvering of the foliage except those carried out immediately upon or soon after exposure. Thus seven out of seventeen inoculations made at once after wounding in January were successful, one was successful (out of seventeen) after two weeks, and one was successful (out of seventeen) after a month's exposure. This result is in agreement with those described above, in which it seems clear that freshly exposed wood is most liable to invasion.

In another large field experiment an attempt was made to ascertain whether any special type of wound was particularly liable to infection. For

this purpose three types of wounds were used: (*a*) where the exposure was trimmed close to a living branch and made smooth with a knife; (*b*) snags left rough as cut with a saw; (*c*) branches split away at a fork or at the junction with the trunk. Spores in an emulsion were applied immediately after the exposures were made (October, 1921) and at intervals throughout the winter until the end of March (1922). All three types of wounds were found liable to infection, as shown by the development of silvered foliage, but snags and split branches gave a higher percentage of positive results than where the exposures were trimmed close to the stems. In addition, wounds in three and four year old branches were infected more frequently than in two and one year old shoots. It is clear therefore that any fresh exposure of wood is liable to attack, but that some types of wounds, e.g., snags and split branches are probably more dangerous than others.

As has long been known, the hyphæ of *Stereum purpureum* are not to be found in the silvered leaves, the pathological symptoms therein being produced by the fungus some distance below in the stem. In 1919 Bintner (1) stated that injured leaves of the Portugal laurel could be invaded to a slight extent by the fungus. We can confirm this statement. If the upper surface of leaves of the Portugal and Cherry laurel be injured and spores or mycelium of *Stereum purpureum* be placed on such a wound, the fungus develops in the immediate vicinity of the injury, killing the cells centrifugally and causing a brown spot to appear. The fungus does not proceed far, however, because the invaded tissues are soon cut off from the healthy parts of the leaf by a cork layer, with the result that the killed portion falls away, causing a "shot-hole" effect. In such experiments the hyphæ kill the leaf cells directly without inducing preliminary symptoms of silvering.

In connection with the investigation of the mode of natural infection by *Stereum purpureum*, some consideration has been paid to the general nature of the micro-organisms which invade the pruning wounds of plum trees. When branches are cut away or are shortened, the exposed extremities soon become invaded by bacteria and fungi unless covered by an impervious antiseptic. These invading organisms invariably cause a dark discoloration of the wood, which often extends far into the tissues below. If the invader be a dangerous type, e.g., *Stereum purpureum*, disease will be established; if on the other hand the organism be relatively innocuous it will continue to exist passively in the discoloured parts, surrounded by healthy tissues, until it dies. A preliminary survey of the diversity of forms which enter these pruning wounds has been made. For this purpose sections of the discoloured tissues were cut near the junction of healthy and diseased wood, and were placed in plum wood agar in Petri dishes. After a few days the organism or organisms present in the wood grew out into the medium whence they could be transferred to other media for

systematic determination. It was usually found that only one type of organism grew out from any one set of sections. Fungi were of more frequent occurrence than bacteria below these wounds, and it was concluded that practically all the discoloration below these exposures was due to organisms of this class. Many different fungi were found in these regions, including *Stereum purpureum*, *Fomes pomaceus*, many pycnidial forms, and several Hyphomycetes, including *Alternaria sp.* Many of these organisms are harmless, and it seems to be entirely fortuitous which of them becomes established. At the outset of invasion several different forms probably compete with one another, but sooner or later one of them grows into the tissues faster than the others. There may also be a succession of fungi following one another in these discoloured tissues. The rate of invasion of pruning wounds by these micro-organisms varies greatly at different times of the year ; in the winter invasion is slow and often practically negligible, but in summer it is relatively fast. This does not imply that infection is not begun during the winter for undoubtedly it is often so effected, but it means that the rate of growth of these organisms is much more rapid at high temperatures than at low ones.

VIII. WOUND PROTECTION IN FRUIT TREES.

It has long been urged that the wounds caused in thinning and pruning should be covered with some protective substance to prevent invasion by micro-organisms, especially by such dangerous fungi as *Stereum purpureum*, although there has been much uncertainty as to the efficacy of the different substances used for this purpose. It is sometimes stated that there is a natural means of protection of such wounds in arborescent plants by the formation of a callus. This view is, however, erroneous, especially with fruit trees. Callus tissues are slow in formation and in plum and apple trees it is only exposures of tissues three to six years old that certainly become completely covered with the lapse of time ; meanwhile the woody parts are unprotected from risk of invasion except for the formation of gum as a wound response, which is only a partial protection against infection. Exposed tissues of greater age are rarely completely covered by callus. Hence from the practical standpoint callus formation is only of limited importance as a protective factor.

A substance placed over a wound to protect it from pathogenic invasion may serve this purpose in two ways ; it may form a cover which cannot be penetrated by micro-organisms, or it may be permeable to fungi and bacteria, but owing to high toxicity it kills these before they have proceeded far. Many substances, e.g., certain kinds of paints, perform both functions. Some of these bodies crack after drying and exposure to the atmosphere with the result that channels are opened into the tissues which if not impregnated by an antiseptic

will thereby become invaded. Again, these protective substances are often cracked by the growth of the tissues below and this may result in exposure. From these considerations it will be seen how important it is to make at least two and preferably several applications of these protective substances at intervals of about three months. It has been shown earlier in this paper that exposures in one year old plum twigs are liable to infection by *Stereum purpureum*, although less so than older tissues. Apart from nursery stock, however, it is entirely impracticable to treat exposures in young twigs with a protective substance. Long observation has shown that it is the exposures in older tissues from three years upwards that are most liable to infection by *Stereum purpureum*, and these undoubtedly should be protected immediately after exposure. If there is delay before the substance is applied, micro-oganisms may have already invaded the tissues to such an extent that any toxic ingredients in the protective substance will not reach them.

An attempt has been made to gauge the efficacy of these protective substances by determining the rate and cause of the discolouration of the tissues below the exposures. For this purpose wounds of different kinds were made, e.g., snags and branch extremities flush with vigorous older branches, and were immediately covered with one of the following substances : gas tar, Stockholm tar, white paint, antifouling paint (used on ships' bottoms), and gentian violet (in concentrated aqueous solution), the last named being used as it is highly toxic to *Stereum purpureum* in cultures. Unprotected control wounds were also kept under observation, and the experiments were repeated at different times of the year. After certain periods the portions of the trees bearing the wounds were cut away and the wounds examined, the presence or absence of micro-oganisms near the limit of discolouration, and as far as possible their nature, being determined. These experiments are not yet complete but a statement of the results to date may be made. It was soon found that snags frequently die without invasion by micro-organisms owing to diversion of the transpiration current, so chief consideration has been given to the types of wounds where parasitic invasion is alone the cause of death of the tissues. A noteworthy feature of these results is that the rate of discolouration below the exposure is much greater in summer than in winter ; in fact in the latter season it is insignificant. This does not mean that wounds arising in the autumn or winter can be ignored, because the dangerous initiation of invasion may have already begun which will proceed with vigour when the temperature rises.

Of the substances used, gas tar and antifouling paint have been most effective in preventing or delaying invasion by micro-organisms. Gas tar has had no appreciable adverse effect upon the tissues when carefully applied. Antifouling paint has unfortunately sometimes killed considerable areas of bark around wounds dressed with it, but it is hoped that arrangements can be made to reduce

its toxicity to host tissues. This paint solidifies homogeneously and is little liable to cracking, but as sold at present it usually requires thickening for most effective use. Stockholm tar has been very disappointing, and both in these experiments and in certain field trials on a large scale it has been found practically useless as a means of protecting tree wounds against fungal attack. Its toxic constituents are probably easily removed by rain. White paint is a fair protection, but although not so good as antifouling paint is less toxic to host tissues than the latter. Gentian violet is only effective for a short time. One other substance, surgical tape, has been tried as a wound cover at the suggestion of Professor Barker. In our preliminary experiments surgical tape has not given particularly good results and for the type of wounds employed has been difficult to apply.

With wounds such as those described, most protective substances will crack in the course of time, hence the necessity for renewal of the dressing. As *Stereum purpureum* most readily invades newly-exposed wood the risk of invasion by it at a later stage when perhaps the protective cover cracks may be considerably reduced. There is also reason to believe that if certain other fungi first invade the exposed tissues, the way is thereby barred for *Stereum purpureum*.

IX. PHYSIOLOGY OF *STEREUM PURPUREUM*.

1. *Longevity of spores.*

The spores of this fungus are small and thin-walled, but nevertheless retain their vitality for considerable periods under certain conditions. For instance, kept at a temperature of 15°-20°C in a laboratory atmosphere of normal humidity, some spores were germinable after fifty-five days, although none survived a period of sixty days. When kept part of this time in a very humid atmosphere about 1 per cent. retained their vitality more than sixty days, but spores deposited at the same time and subjected to extreme desiccation were all dead in two days. At 24°C spores kept in a relatively dry atmosphere ceased to germinate after twelve days. It seems therefore that a high degree of desiccation is more inimical to retention of vitality than moderate fluctuations of temperature.

2. *Optimum temperature for growth.*

Preliminary tests indicate that on artificial media in Petri dishes growth is best at a temperature round about 30°C.

3. *Toxicity of various substances to Stereum purpureum.*

In connection with further enquiries as to the possibility of curing silver-leaf disease by injection (cf. Silver-leaf Disease III.), a large number of tests have been made to determine the toxicity of various substances to *Stereum*

purpureum in a liquid medium. In recent years much work has been done by Humphrey and Flemming (12) in America to determine the relative toxicity of various chemicals to certain fungi, and Miss Rumbold (14) has investigated the toxic effect of dyes and other substances on chestnut trees.

Our experiments were designed to find out the inhibiting concentration of certain antiseptics to further growth of *Stereum purpureum* when introduced into a liquid medium on small fragments of agar. Dox's medium containing 15 or 10 grams of sugar per litre was chosen for these tests and the method of determining the inhibiting concentration of the toxic ingredient was as follows:—

(1) Tubes were prepared containing 5 cc. of Dox's medium at double strength. These were sterilised by intermittent steaming.

(2) A " dilution " series of tubes was prepared of the toxic substance with distilled water. These tubes were sterilised by steam.

(3) Subsequently the contents of a tube of culture medium and a tube containing the toxic substance were mixed by pouring one to the other several times, the resulting mixture being divided between the two tubes. This process of mixing was carried out without appreciable risk of contamination, only one tube in 600 being spoilt in this way.

The following is a list of minimum concentrations of various substances found to inhibit further growth of *Stereum purpureum* :—

Gentian Violet (Gürr)	about	0.02	per cent.
Methyl Violet 5B (Grübler)	,,	0.003	,,
Methyl Violet 6B (Gürr)	,,	0.002	,,
Brilliant Green (Gürr)	,,	0.008	,,
Bismarck Brown	,,	0.04	,,
Congo Red	,,	0.4	,,
Trypan Blue	,,	0.4	,,
Methylene Blue—med. pur. (Grübler)	,,	0.03	,,
Erythrosin	,,	0.2	,,
Eosin	,,	1.0	,,
Phenol	,,	0.08	,,
Sod. phenol sulphonate	,,	0.4	,,
Sod. dinitrobenzene sulphonate	,,	0.15	,,
Sod. alizarin sulphonate	,,	0.005	,,
Potassium fluoride	,,	0.3	,,
Potassium oxalate	,,	1.0	,,
Sod. arsenate	,,	1.0	,,
Borax	,,	0.2	,,
Dimol	,,	0.013	,,
Superol	,,	0.00003	,,

Dimol is an intestinal disinfectant and superol is a proprietary antiseptic frequently used to prevent mould growths upon raw rubber in the Eastern tropics. Superol is by far the most toxic to *Stereum purpureum* of all the substances used, and it is also highly inimical to the growth of other fungi such as *Botrytis cinerea*, *Penicillium expansum*, and *Fusarium coeruleum*. On the other hand, superol appears to be less toxic to the higher plants, e.g., plum shoots, than such a substance as gentian violet.

X. PHYSIOLOGY OF SILVERED LEAVES.

Some work of a preliminary kind has been done upon the photosynthetic activity of silvered leaves, the results of which indicate that the symptoms of silvering result in considerable disturbance from the normal. If Sach's test be applied to moderately silvered and healthy plum leaves at the end of a day of bright sunlight, the silvered leaves are usually found to contain more starch than the healthy ones. In this connection it must be pointed out that translocation of carbohydrates from the lamina is slower in a silvered than in a healthy leaf ; in fact in a heavily silvered leaf some of the starch in certain areas seems irremovable however long the leaf be kept in darkness. A part therefore of the greater starch content of a silvered leaf may be due to a decrease in the rate of translocation. An attempt has been made by Mr. Inamdar to compare directly the rate of carbon-assimilation of moderately silvered Victoria plum leaves with healthy ones, using the apparatus employed by Dr. F. F. Blackman in his work on photosynthesis. Mr. Inamdar found that a moderately silvered leaf assimilated less actively than a healthy leaf, but still at a fair rate. It would appear that the usually greater starch content of silvered leaves is due to a diminished rate of translocation rather than to increased photosynthetic power.

Another characteristic of silvered foliage is that it wilts before healthy foliage. The more heavily silvered are the leaves the quicker do they wilt when the branch bearing them is cut from the tree and placed in water. Thus in one experiment a moderately silvered plum shoot was somewhat wilted two days after being placed in water in the laboratory, a badly silvered shoot was quite wilted, while the leaves of a healthy shoot were still fully turgid. The cause of this more rapid wilting of silvered foliage is not clear, but there is some evidence that the stomata of silvered leaves have partly lost their power of adjustability so that they remain wide open for longer periods than do healthy stomata. On the other hand the early wilting of silvered leaves may be due to a more general physiological disturbance of the tissues through which the transpiration current passes.

It may be mentioned that there is no heredity transmission of silver-leaf disease, for seeds of a silvered plant of *Lupinus arboreus* (attacked by *Stereum purpureum*) gave rise only to normal seedlings.

XI. "TRUE" AND "FALSE" SILVER-LEAF.

Bintner (1) has attempted to distinguish between silver-leaf caused by *Stereum purpureum* and the silvery symptoms which are sometimes found in herbaceous plants and which are unassociated with this fungus. The former he denotes as "true" and the latter as "false" silver-leaf disease. In our experience silvery symptoms in leaves represent a whole complex of phenomena which cannot be classified in this simple manner. In an earlier paper of this series (3) curious examples* of silvered foliage were described, due respectively to insect attack and to excessive water-loss, as well as examples which histologically as well as superficially showed all the symptoms of silver-leaf disease caused by *Stereum purpureum*. In silvered plum seedlings and in silvered herbaceous plants, e.g., *Paeonia officinalis*, *Urtica dioica*, *Lamium album*, etc., the affected leaves show not only the partial separation of the epidermis from the mesophyll, but the same tendency for the mesophyll cells to separate one from the other as in silvered plum foliage caused by *Stereum purpureum*. With such characters in common it is impossible to speak of "true" and "false" silver-leaf. In this connection it is well to reiterate that in silver-leaf caused by *Stereum purpureum* the influence of the fungus in causing the peculiar histological symptoms is entirely indirect. Our point of view is that although the direct cause (at present unknown) of the histological disturbance ordinarily associated with silver-leaf disease is probably the same throughout, the indirect causes (e.g., *Stereum purpureum*) are very diverse. The really serious effect of silver-leaf disease caused in fruit trees by *Stereum purpureum* is not the silvering of the foliage, which is only an accessory symptom, but the dying back of the trees due to permeation of the wood by the mycelium. From the fruit-growers' standpoint silver-leaf disease is due to *Stereum purpureum* and that is the enemy to be combated.

* Similar silvering effects have recently been seen in poplar leaves affected by *Taphrina aurea* where the upper surface was distinctly silvery owing to optical disturbance although there was no internal separation of the mesophyll cells. Likewise certain varieties of apples showed a peculiar silvery sheen of the foliage after the long drought of 1921 although there was no internal disturbance. In these apples the epidermal cells appeared to have lost their turgidity.

XII. TREATMENT.

It is sometimes claimed that a cure has been discovered for silver-leaf disease, but at present we know of no cure for this disease which can be recommended without grave risk of failure. Some of these claims are based upon the behaviour of a few trees in which the forces of natural recovery have prevailed and not the treatment.

With the recognition of the factor of natural recovery it is clear that anything which can be done to aid it, will be of assistance in the struggle against silver-leaf disease. Good drainage, good cultivation and the facilitation of active growth by any means whatsoever, all favour the forces of natural recovery against this disease. Vigorous growth is often promoted by the addition of manures, either farmyard or artificial. Certain preliminary trials with artificial manures have given hopeful results as regards leading to recovery of silvered trees, but trials on a larger scale will have to be carried out before confident advice can be given. In these preliminary tests applications of kainit and basic slag to silvered plum trees in December and February had beneficial results.

Ring-barking of silvered branches is sometimes stated to be a cure for the disease. In this operation a ring of bark a quarter of an inch in diameter and about three-quarters of the circumference is cut away in the spring some distance below the lower extension of silvered foliage. In some trees which we have seen, this operation has been followed by recovery,* but the number of trees as yet treated in this way are too small to base final conclusions upon. We have ourselves experimented with this method on a considerable scale, but with little success so far.

In the previous paper of this series on silver-leaf disease (3) preliminary work on attempts at curative treatment of silver-leaf disease by injection was described. This has been continued, but without success, and at present there seems to be little hope of discovering a substance which can be easily injected into a silvered fruit tree, which is readily diffusible, and which while harmless to the host is toxic to *Stereum purpureum*. It is not worth while to describe these injection experiments in detail. Suffice it to say that dyes such as eosin, gentian violet and other substances such as sodium arsenate, were placed in solid form in a series of holes spirally arranged around the basal part of the trunks of affected trees in the hope that they would readily diffuse into the tissues permeated by the fungus when the transpiration current became active.

* Mr. E. Neal, gardener to Mr. E. Nix, of Tilgate, Sussex, is believed to be the first person to have employed this method, and we are much indebted to him for opportunities to examine the trees he treated in this way.

Where injection took place into wood killed by the action of *Stereum purpureum*, and which probably was no longer functional in carrying the sap stream, great differences in diffusibility were shown by these substances : e.g., gentian violet was far less diffusible than eosin.

Treatment by plant sanitation.

If silver-leaf disease cannot be cured in the medical sense, it can be prevented in great measure by following the methods of plant sanitation (5). Preventive measures fall under three heads :

(1) Prevention of the fungus, *Stereum purpureum*, from fructifying within and on the confines of fruit plantations, i.e., the abolition of the source of infection as far as this is practically possible.

(2) Avoidance of giving opportunity to *Stereum purpureum* to invade fruit trees through wounds. In the past there has been far too much cutting out of branches of mature trees. Fruit trees should be shaped properly when young, after which they should be left alone, apart from any necessary pruning of young shoots.

(3) If wounds must be made in fruit trees as in certain nursery operations and in cutting away branches broken by excessive weight of fruit, the exposures should be covered *immediately* by an antiseptic, such as gas tar. A second application of the antiseptic should be given within three months. If continuous protection could be afforded to these wounds, the fungus could not enter ; the present state of our knowledge indicates that the most critical time for invasion by *Stereum purpureum* is immediately after exposure, so that this should be avoided at all costs.

In recent years the Ministry of Agriculture and Fisheries have insisted, by administrative order, upon the eradication of all dead wood likely to harbour *Stereum purpureum* in fruit plantations. One result of this Order has been the removal of thousands of plum and apple trees killed through silver-leaf disease, which were a prolific source of infection. A change has recently been made in the date by which cutting out of dead wood in fruit plantations must be made (Silver-leaf Order of 1923). The present date is July 15th, which will lead to the removal of dead wood when there is a clear differentiation from healthy trees and which coincides with the period when spore production by *Stereum purpureum* is usually at a minimum. Tree stumps such a poplars on the borders of fruit gardens should be eradicated, as they are a common source of *Stereum purpureum*, and where the fungus fructifies abundantly on stumps of trees just outside fruit

plantations, an arrangement should be made, if possible, to remove them. The prevention of the formation of fresh crops of spores by the destruction of dead wood in fruit plantations is already having an effect in reducing the incidence of silver-leaf disease. In destroying fruit trees which have died from this disease, care should be taken to remove the main roots in case these become exposed and give rise to fruit-bodies of the fungus. There is no reason why new trees should not be planted where old ones have been removed, as the danger of root infection is negligible. No attempt should be made to keep grubbed trees piled on the premises, otherwise fructifications will arise on them. In Kent it has been found that dead plum trees can be used for making charcoal.

It is less easy to give explicit advice upon the desirability of cutting out silvered branches of fruit trees. With apples, in which the rate of natural recovery is high, it is generally inadvisable to removed silvered branches unless these are actually beginning to die back. With plums the advisability of cutting silvered branches away depends entirely upon circumstances. If certain branches have just begun to be effected, these can often be removed with advantage to the rest of the tree, provided that the wood actually infected is cut away. If, however, the tree is generally silvered, the fungus probably exists in the trunk where it cannot be excised, and the only sound policy is to wait until the tree begins to die back or alternatively to recover. Silvered branches often bear much fruit and there is no danger of infection from them until they die back.

In regrafting apple trees there is grave risk of infection by *Stereum purpureum*, and with such a variety as Newton Wonder the chances of attack are so great that in general it seems inadvisable to regraft this variety. Where apples are regrafted, it is usual to head them back some months before the grafts are inserted. In such cases the exposed surfaces should be covered with a protective substance, such as gas tar, and immediately before the insertion of the grafts the stems should again be cut back, so as to eliminate all discoloured tissues. The exposures should then be covered with clay, " pug " or grafting wax.

In nursery work, attention has already been called to the chief opportunities for infection by *Stereum purpureum*. If silver-leaf disease appears in a nursery the only safe rule is to destroy forthwith the affected trees. Reputable firms will not countenance the presence of silvered stocks or worked trees upon their premises. Unfortunately, fruit trees are sometimes propagated casually from silvered suckers by persons with no reputation to lose. If these suckers actually contain *Stereum purpureum*, the fungus will probably spread into and kill the young trees after a season or two. Examples of this kind have actually been seen. The remedy for this would appear to be in the public limiting their purchases to reputable firms who would not countenance such a practice.

XIII. SUMMARY.

(1) Some additional hosts for silver-leaf disease caused by *Stereum purpureum* are mentioned, including certain kinds of roses and pears.

(2) Attention is called to the damage recently inflicted by the disease upon peaches (under glass), Morello cherries, and certain varieties of apple, e.g., Newton Wonder and Early Victoria.

(3) The incidence of certain, almost epidemic, outbreaks of silver-leaf disease in apples and plums, is related to previous careless treatment of the trees, especially the provision of facilities for infection through cutting out large numbers of branches.

(4) The occurrence of silver-leaf disease in nurseries is discussed, and the critical times for infection of nursery stock are pointed out.

(5) The influence of the type of stock on the susceptibility of Victoria plums is considered. All plum stocks so far tested have proved susceptible to artificial infection by *Stereum purpureum*, but some are more resistant than others.

(6) Arguments, partly based upon pathogenicity, are advanced against the separation of *Stereum rugosiusculum* from *Stereum purpureum*.

(7) The preference of *Stereum purpureum* for woody tissues uninvaded by other micro-organisms is pointed out.

(8) The effect of the fungus upon invaded plum wood, including the process of gum formation, is described.

(9) The causes of natural recovery of silvered fruit trees are considered; it has been found that one of the chief factors is the formation of a peculiar zone of dark gummy substances in the periphery of the diseased wood, which cannot be permeated by the fungus.

(10) Further information is given as to the exact means by which *Stereum purpureum* infects fruit trees. It can readily infect newly-exposed woody tissues from one year old upwards, and there is evidence that such tissues are more readily infected by spores than tissues which have been long exposed. Snags and broken branches are particularly liable to infection by *Stereum purpureum*.

(11) A preliminary investigation has been made upon the nature of the micro-organisms which invade pruning wounds of plum trees. These organisms are chiefly fungi of different kinds,

(12) Various protective substances for dressing wounds in fruit trees have been tested. Gas tar has generally given the best results so far, and there is no danger of this substance damaging the bark if carefully applied. The use of Stockholm tar for this purpose cannot be recommended.

(13) Information is given as to the longevity of the spores of *Stereum purpureum* under different conditions, and as to the toxicity of various substances to the fungus in culture.

(14) Silvered plum leaves photosynthesise, but less actively than healthy leaves. Translocation of carbohydrates from silvered leaves proceeds more slowly than from healthy leaves. Silvered leaves wilt more readily than healthy ones.

(15) The attempt to differentiate "true" from "false" silver-leaf is considered to be invalid.

(16) Treatment :

(*a*) There is no known *cure* for silver-leaf disease, but every effort should be made to facilitate natural recovery of silvered trees by good cultivation and manuring.

(*b*) The disease can be *prevented* in great measure by the destruction of dead wood within and on the confines of fruit plantations on which *Stereum purpureum* might develop, by thinning and pruning fruit trees no more than is absolutely necessary, and by covering exposed tissues immediately with an antiseptic such as gas tar.

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